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2MASS J05185995−2828372: DISCOVERY OF AN UNRESOLVED L/T BINARY

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ABSTRACT

We present the peculiar near-infrared spectrum of the newly discovered brown dwarf 2MASS J05185995−2828372, identified in the Two Micron All Sky Survey. Features characteristic of both L and T dwarfs are present, namely strong carbon monoxide absorption in K-band, strong methane absorption in J- and H-bands, and red near-infrared colors. We consider several scenarios that could produce these features and conclude that the object is most likely to be an unresolved L/T binary system. We discuss how the estimated photometric properties of this object are consistent with the observed J-band brightening of brown dwarfs between late-L and early-T dwarfs, making detailed study of this system an important probe of the L/T transition.

Subject headings: binaries:general—stars: low-mass, brown dwarfs—stars: individual (2MASS J05185995−2828372)

1. INTRODUCTION

The existence of brown dwarfs, low-mass (M $\lesssim$ 0.075 $M_\odot$) objects that form like stars but are incapable of maintaining core hydrogen fusion, was first postulated by Kumar (1962). After several decades of unsuccessful searches, well over 100 brown dwarfs are currently known, primarily as a consequence of the availability of deep far-red and infrared sky surveys (Epchtein et al. 1999; Skrutskie et al. 1997; York et al. 2000, DENIS, 2MASS,SDSS). Without a long-lived energy source, brown dwarfs cool rapidly, exhibiting spectra dominated by a sequence of complex molecular bands. Metal hydride absorption (e.g., FeH, CrH, and CaH) replaces titanium oxide at optical wavelengths as the effective temperature falls below 2100 K, and the spectral type evolves from type M to type L (Kirkpatrick et al. 1999; Chabrier, Baraffe, Allard, & Hauschildt 2000). As the temperature drops below 1300 K, methane forms in the outer atmosphere (Tsuji 1964) and the strong absorption at 1–3 μm leads to significantly bluer near-infrared colors. These are T dwarfs (Burgasser et al. 2002a; Geballe et al. 2002).

We are currently using near-infrared photometry from the Two Micron All-Sky Survey (Skrutskie et al. 1997, 2MASS) to search for all late-type M and L dwarfs lying within 20 parsecs of the Sun (Cruz et al. 2003). In the course of follow-up observations, we have identified a cool dwarf which appears to break the current spectral classification paradigm. 2MASS J05185995−2828372 (hereafter, 2M 0518) was selected for observation based on its red $(J - K_s)$ color of 1.82 magnitudes and its relatively bright apparent magnitude, J = 15.98. The peculiar near-infrared spectrum of this object, however, exhibits both L and T dwarf spectral features. The following section describes our observations and § 3 discusses possible explanations for the observed properties of this intriguing object.

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2. OBSERVATIONS

2M 0518's location on the color-color diagram is shown in Figure 1 and a finder chart is given in Figure 2. Near-infrared spectroscopy was obtained on 2003 September 19 with SpeX (Rayner et al. 2003) on the NASA Infrared Telescope Facility (IRTF) on Mauna Kea. Observations were taken in low-resolution (R=250) prism mode yielding a single order from 0.8–2.5 μm, encompassing the J-, H-, and K-bands (centered at 1.2,

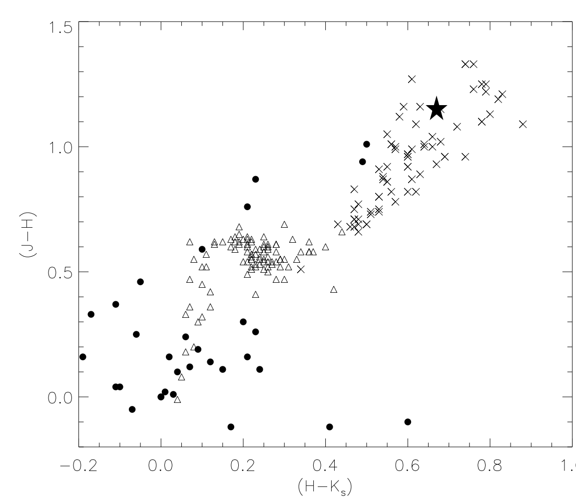

Fig. 1.— Color-color diagram for 2M 0518 (*five-pointed star*), late-type stars (*triangles*), L dwarfs (*crosses*), and T dwarfs (*circles*).

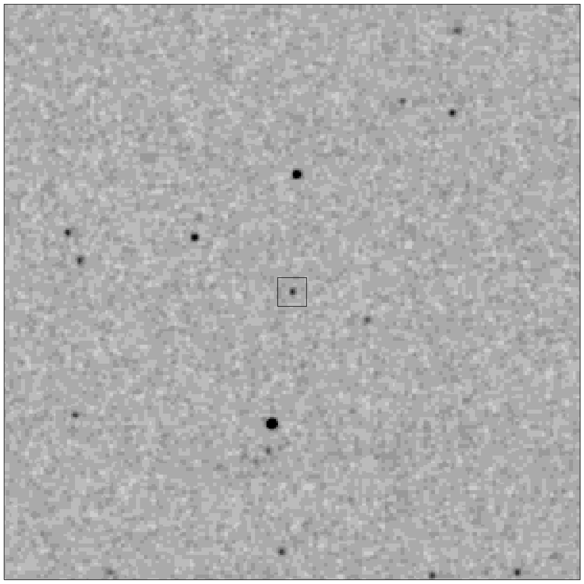

FIG. 2.— K_S-band finder chart for 2M 0518 as taken from the 2MASS All-Sky Quicklook Image Service. The epoch of the image is 1999 January 06. Images are 5′ on each side, with north up and east to the left.

1.6, 2.2 μm, respectively). For the flux-calibration, an A0 star (HD 36965) was observed immediately after the target observation and at a similar airmass. This was followed by acquisition of flat-field and arc-line calibration frames. Conditions were good, although the data were obtained during morning twilight and at an airmass of 1.6. The data were flat-fielded, extracted, wavelength-calibrated, and telluric-corrected with Spextool (Cushing, Vacca, & Rayner 2003; Vacca, Cushing, & Rayner 2003). The spectrum of 2M 0518 is shown in Figure 3 with reference spectra of an L6, T0, and T4 obtained with the same instrumental setup. The near-infrared observational properties for all of these objects are listed in Table 1.

3. DISCUSSION

While 2M 0518 lies at the red end of the L dwarf sequence, as shown in Figure 1, its spectrum clearly shows methane absorption, the hallmark characteristic of T dwarfs. Additionally, the relative strengths of the absorption bands (specifically H_2O, CH_4, and CO) are anomalous and are not consistent with either a classical L or T dwarf. The strong methane absorption in J- and H-bands, and water absorption in J-band is consistent with a mid-T dwarf (cf. 2M 2254 in Figure 3), whereas the weak methane feature in K-band more resembles an early-T dwarf (cf. SDSS 0423 in Figure 3). In addition, carbon monoxide absorption in the K-band is typical of late-L dwarfs (cf. 2M 0103 in Figure 3). In the following section we consider four possible explanations for the unusual properties of 2M 0518.

3.1. *Possible Scenarios*

Youth. Two characteristics of young objects are reddening by dust and spectral features indicative of low gravity. The above-average red color of young objects is attributed to circumstellar dust or line-of-sight reddening. Dust preferentially absorbs shorter wavelength radiation, changing the slope of the spectrum and reddening the colors, but cannot account for the anomalous absorption bands strengths observed in 2M 0518. Low gravity, the other characteristic of youth, does affect K-band spectral features. In particular, a key signature of low gravity is a decrease in the flux suppression in K-band due to the weakening of H_2 collision-induced absorption (CIA) (Burrows et al. 2002; Saumon et al. 1994). However, the downward slope of the K-band peak in the spectrum of 2M 0518 does not indicate weak CIA H_2 absorption. The unusual spectral features of 2M 0518 cannot be explained by either reddening or low gravity and thus the object is not likely to be a young T dwarf.

Single L/T Transition Object. An example of a transition object is SDSS 04234858−0414035 which is typed as L7.5 in the optical and T0 in the near-infrared and also has red colors (J. D. Kirkpatrick et al., in preparation; Geballe et al. (2002); Table 1). This object is discussed in detail by J. D. Kirkpatrick et al. (in preparation) and its spectrum is shown in Figure 3. In general, L/T transition objects have weak methane absorption in K-band and almost non-existent methane features in J- and H-bands (Geballe et al. 2002). In 2M 0518, we see the opposite—strong methane absorption in H-band while weak at K-band. The spectrum of 2M 0518 does not fit the description of a single L/T transition object.

Low Metallicity. The weakness of the K-band methane and carbon monoxide features in the spectrum of 2M 0518 may be attributed to low metallicity. In metal poor dwarfs, increased CIA H_2 absorption significantly masks these features and results in blue near-infrared colors (Burgasser et al. 2003). There is no evidence for enhanced CIA H_2 absorption in the spectrum of 2M 0518 and its near-infrared colors are red, not blue. It is highly unlikely that 2M 0518 is metal poor.

Unresolved L/T Binary. Late-L and mid-T dwarfs have similar J-band absolute magnitudes but very different near-infrared colors. Since there is no methane absorption in L dwarfs, they are much brighter than T dwarfs in K-band, and thus their near-infrared colors are also redder. For this reason, in a late-L/mid-T binary system, the L dwarf would be expected to dominate the joint flux distribution longward of $\sim$1.6 μm, partially filling in the methane absorption in H- and K-bands and producing red $(J-K)$ composite colors. This is in qualitative agreement with the available 2MASS photometry and our spectrum of 2M 0518.

Of these four options, the last offers the most plausible means of explaining the observed properties of 2M 0518 and, in the following section, we discuss the binary scenario in detail.

3.2. *2M 0518 as an Unresolved L/T Binary*

We have made a qualitative attempt at reproducing the spectrum of 2M 0518 by separately combining spectra of four mid/late-L dwarfs with three early/mid-T dwarfs using various scale factors. The best qualitative match is clearly obtained by summing the red L6, 2MASS J01033203+1935361, with the T4, 2MASS J22541892+3123498, weighted by a factor of 1.2, after both spectra have been normalized to 1.3 μm. The individual spectra of 2M 0103 and 2M 2254 are shown in Figure 3 and their scaled sum is superimposed on the spectrum of 2M 0518 in Figure 4. The measured

Table 1. Near-infrared Observational Properties for Objects Plotted in Figure 3

α_{J2000}	δ	Sp. Type	2MASS J	2MASS H	2MASS K_s	$(J-H)$	$(H-K_s)$	$(J-K_s)$	Ref.
01 03 32.03	+19 35 36.1	L6	16.29±0.08	14.90±0.06	14.15±0.06	1.39±0.10	0.75±0.08	2.14±0.10	1
04 23 48.58	−04 14 03.5	T0	14.47±0.03	13.46±0.04	12.93±0.03	1.00±0.04	0.53±0.05	1.54±0.04	2,3,4
22 54 18.92	+31 23 49.8	T4	15.26±0.05	15.02±0.08	14.90±0.15	0.24±0.09	0.12±0.17	0.36±0.15	5,6
05 18 59.95	−28 28 37.2	?	15.98±0.10	14.83±0.07	14.16±0.07	1.15±0.12	0.67±0.10	1.82±0.12	

References. — (1) Kirkpatrick et al. (2000); (2) Geballe et al. (2002); (3) Schneider et al. (2002); (4) J. D. Kirkpatrick et al. (in preparation); (5) Burgasser et al. (2002a); (6) Burgasser et al. (2004)

Note. — Units of right ascension are hours, minutes, seconds, and units of declination are degrees, arcminutes, and arcseconds.

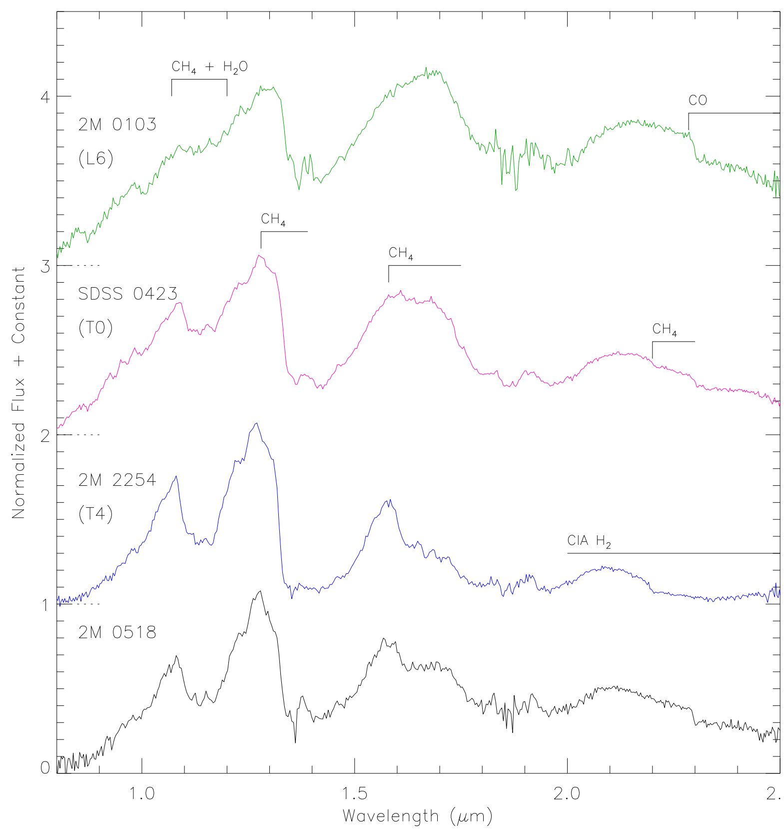

Fig. 3.— Spectrum of 2M 0518 (*bottom*) and reference spectra for an L6, T0, and T4. Dotted lines mark the zero points for each spectrum.

colors of the composite spectrum are $(J-H) = 0.9$, $(H-K_s) = 0.6$, $(J-K_s) = 1.5$ and are comparable to the colors of 2M 0518 (listed in Table 1). Based on the overall agreement between the spectral features and the resultant colors of the combined spectrum with those of 2M 0518, we find this scenario to be the most compelling and conclude that 2M 0518 is likely to be an unresolved binary system composed of a late-L dwarf and a mid-T dwarf.

The two other candidate L/T binary systems, 2MASSJ 08503593+1057156 and 2MASSJ 17281150+3948593, were discovered with HST WFPC2 imaging (Reid et al. 2001; Gizis et al. 2003). Neither these data nor ground based spectroscopy, however, are able to robustly obtain spectral type estimates for the secondaries. J. E. Gizis et al. (in preparation) have obtained HST NICMOS imaging that measures the near-infrared properties of the individual components and thus will definitively determine if these systems are comprised of an L and T dwarf or two L dwarfs.

We adopt $M_J = 13.9$ for the L6 component using the spectral type/absolute magnitude relation found by Tinney, Burgasser, & Kirkpatrick (2003). While scaling the T4 component by 1.2 causes the J-band peak height of the T4 to be higher than that of the L dwarf, the T4 still has a fainter J magnitude due to strong water and methane absorbtion. We measure $\Delta J = 0.1$, yielding $M_J = 14.0$ for the T4 component. This estimate is very similar to the $M_J = 13.9$ measured for the T3,

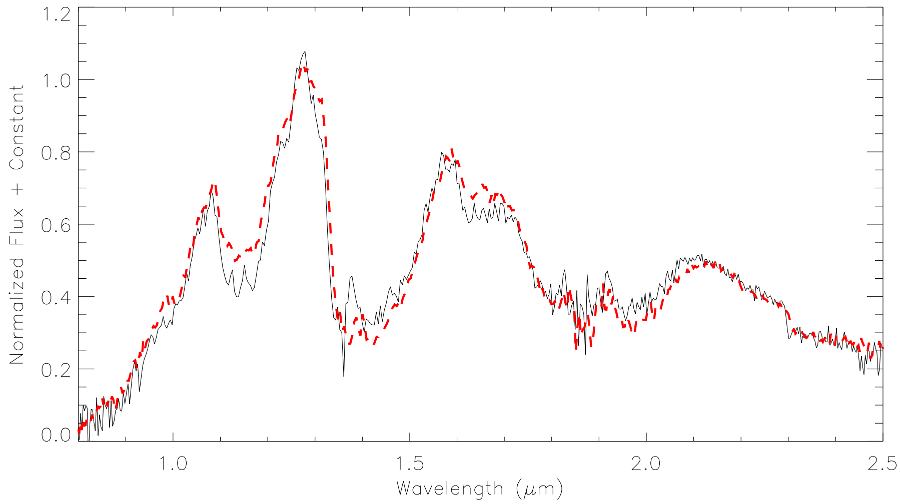

FIG. 4.— Spectrum of 2M 0518 (*solid*) with the scaled sum of 2M 0103 (L6) and 2M 2254 (T4) (*dashed*) superimposed.

SDSS J10210969−0304201, and $M_J = 13.8$ for the T5, 2MASS J05591914−1404488, the two objects with parallax measurements that have spectral types closest to T4.

While tentative, this observation further supports the argument that there is a *physical* brightening of T dwarfs at J-band compared to L dwarfs as observed by Dahn et al. (2002) and Tinney, Burgasser, & Kirkpatrick (2003) and is more likely due to the clearing of clouds and an increased optical depth as proposed by Burgasser et al. (2002b) rather than the age selection effects as suggested by Tsuji & Nakajima (2003).

Combining the individual absolute magnitude estimates for the two components yields a photometric distance of 36 pc for 2M 0518. If the 2M 0518 system can be resolved and the components can be studied separately, this object will provide strong constraints on substellar evolutionary models and will be an important probe of the poorly understood L/T transition.

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